Project Management Challenge 2007

Track: Case Study Insights at NASA

Case Study:

Extracting Trends and Lessons Learned From Project Problems and Solutions

NASA Goddard Space Flight Center

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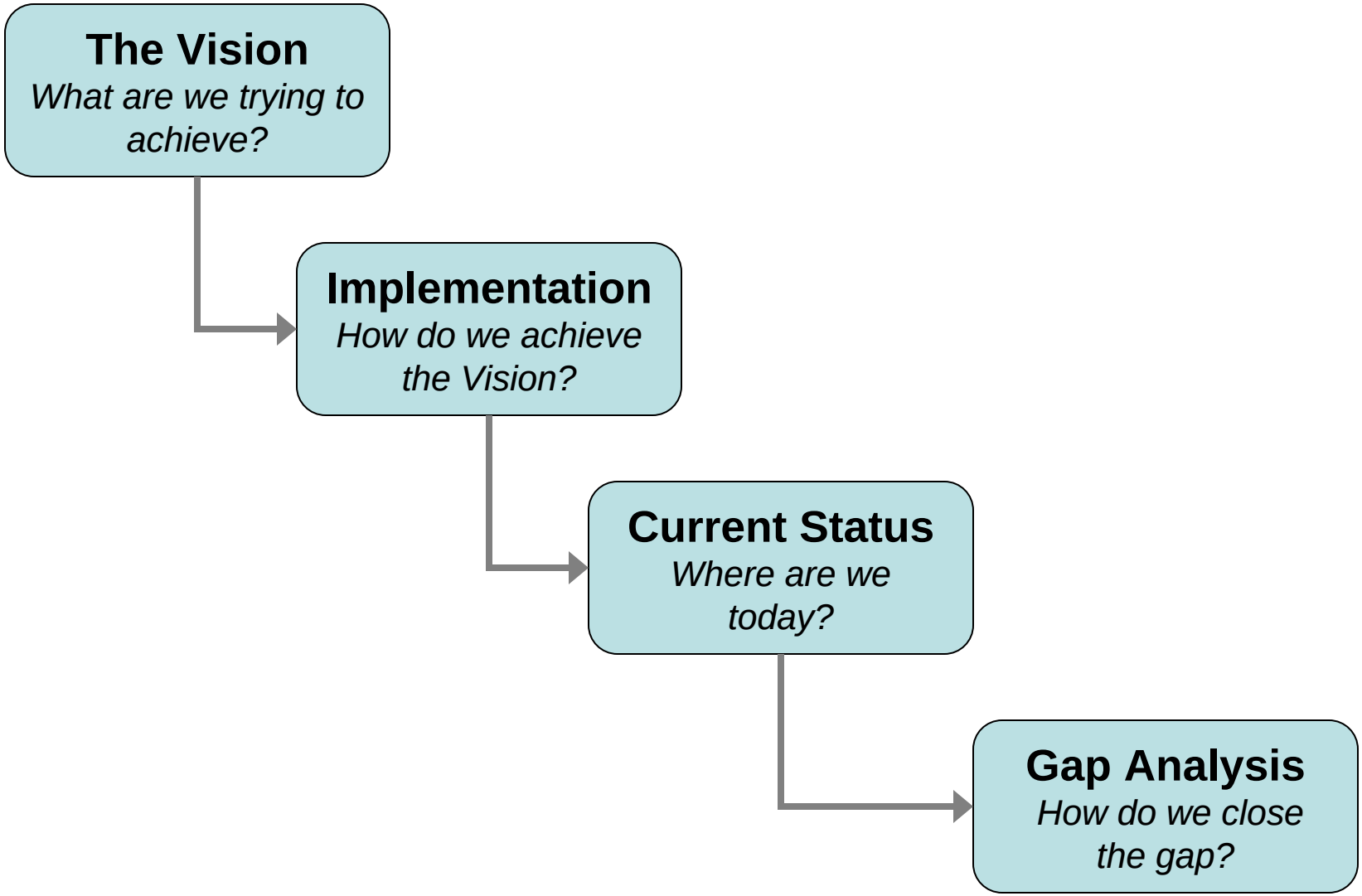
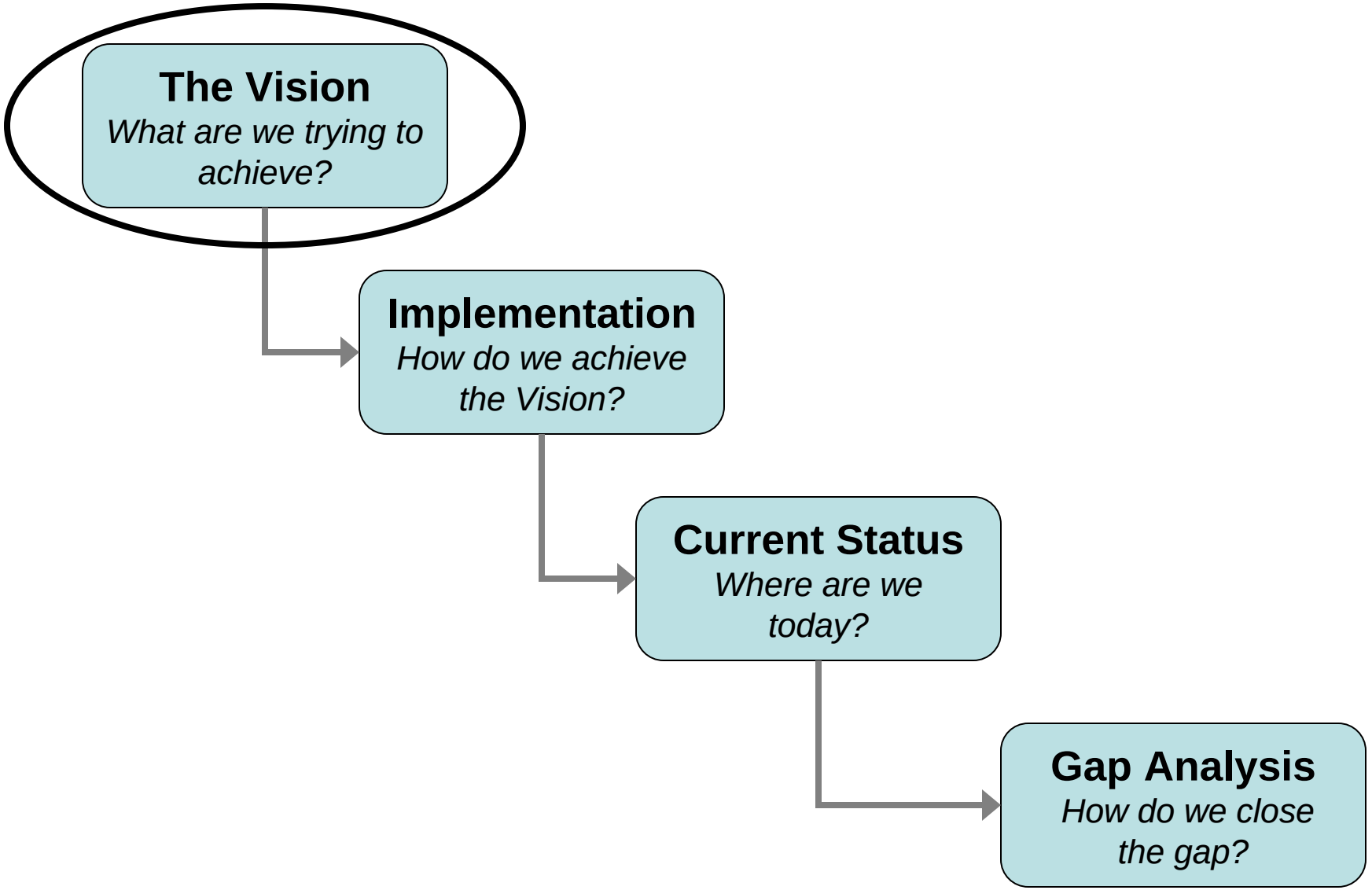
Presentation Outline



The Anomaly Management Vision



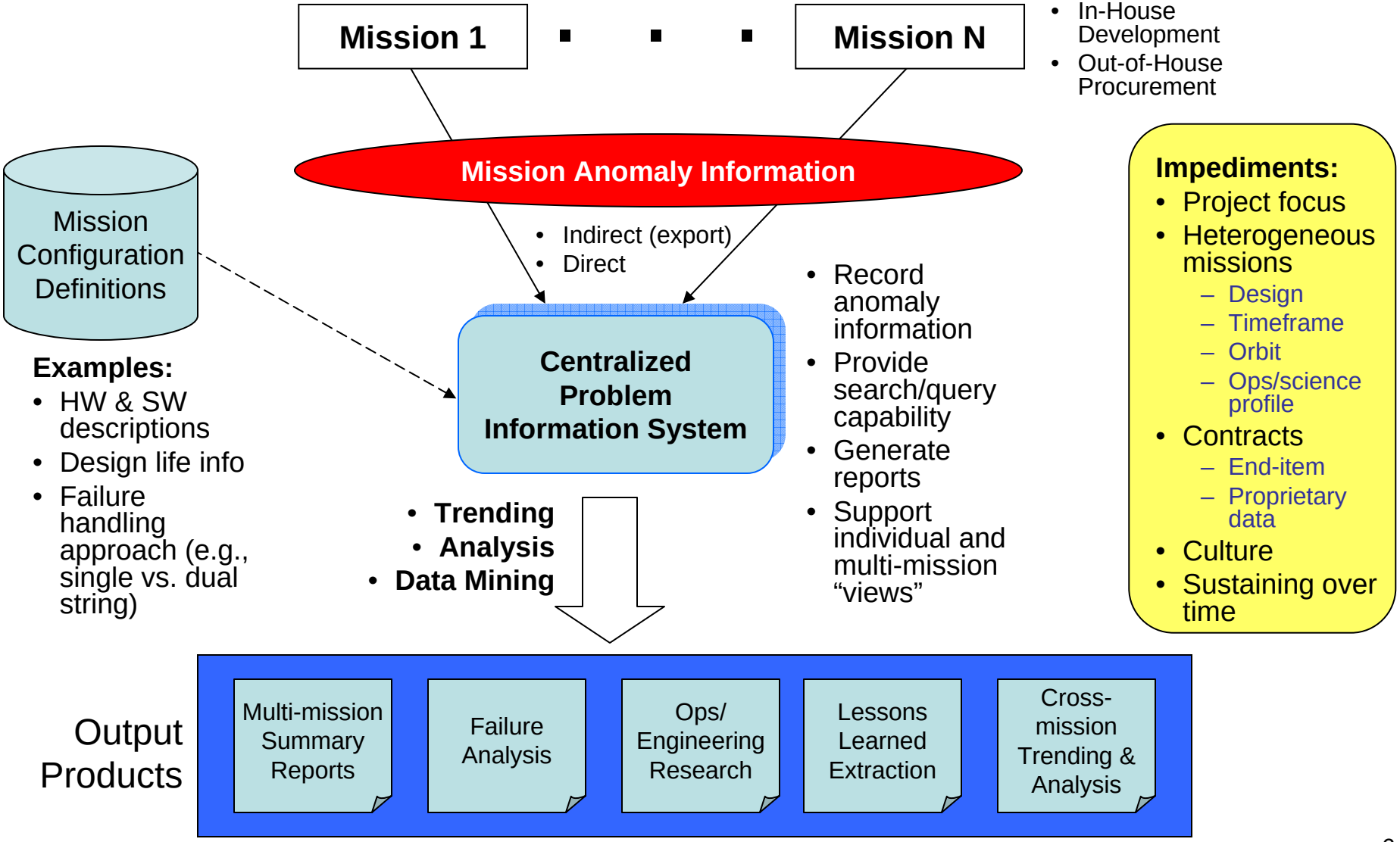
Anomaly Management Vision

- GSFC has well documented requirements, procedures, and best practices for mission-related problem management, reporting, analysis, and trending
- GSFC efficiently verifies adherence to the established problem management requirements and established best practices
- All GSFC development and on-orbit missions use a consistent problem management process and philosophy
  - Flexible enough to handle the diversity of spacecraft missions in the organization, enforcing certain fundamental “rules” for all missions, but allowing some differences where appropriate in other areas
    - Example: HST vs. Small Explorer Program
    - Recognizes that risks and budgets can be very different among programs
  - Applies to all missions that the organization is responsible for, regardless of whether or not the missions are built and/or flown “in-house”
    - NASA responsible for mission success regardless of approach to development or operations (i.e., in or out of house)
    - Out-of-house missions do pose unique challenges

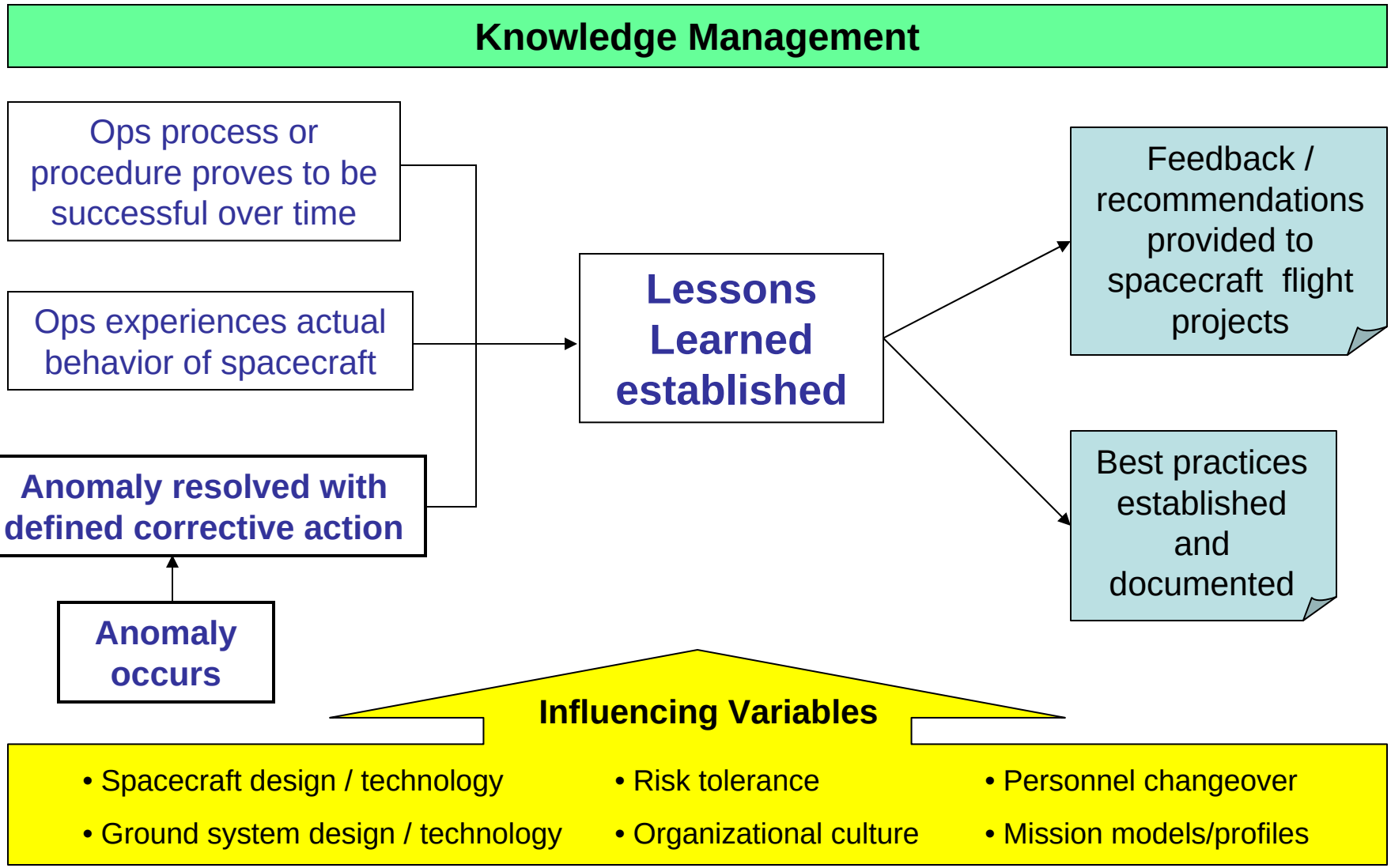
Anomaly Management Vision (cont)

- GSFC provides online access to accurate mission configuration information for all Goddard managed missions in development and operations
  - Example: Subsystems, components, orbit configuration, duty cycles
- GSFC analyzes and trends problems across development and on-orbit missions
  - Individual missions, across mission "families", across all missions
  - Consistent use of a variety of Categorizations (e.g., failure type, root cause, impact)
- GSFC extracts appropriate "Lessons Learned" information from the problem and solution space and apply these back into the development and operations processes
  - Examples: improvements in Rules/Best Practices for development, testing, and operations; planned vs. actual hardware & software performance

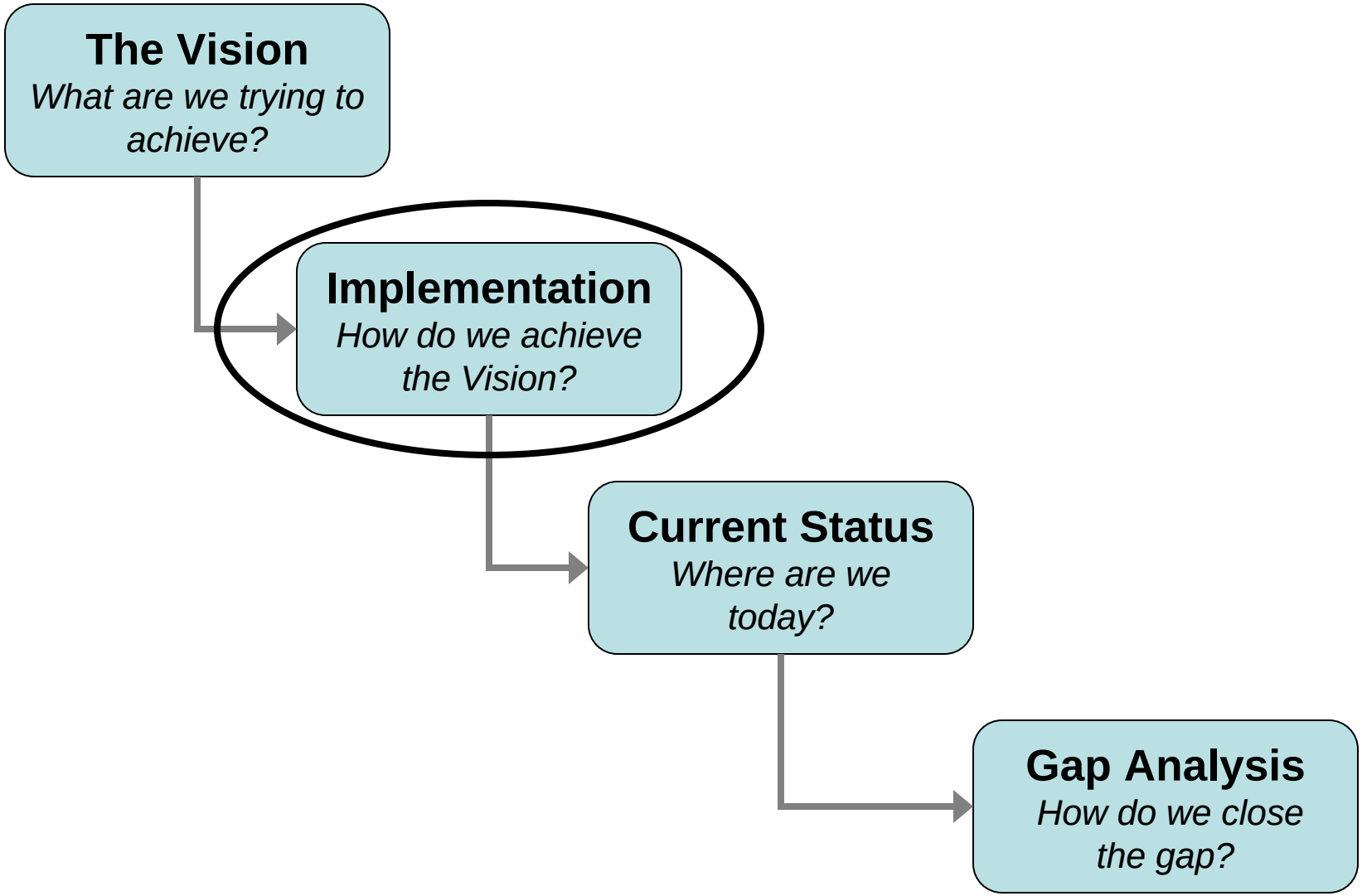
Problem Management Information Flow



Lessons Learned Feedback Process



Implementing The Vision



Implementation Approach

- Ensure appropriate requirements are officially documented so that they apply to all missions in development and operations
  - Goddard Procedures and Requirements Documents (GPR's)
  - Mission Assurance Requirements (MAR) Document (per mission), with the Mission Assurance Guideline (MAG) document as a template
- Establish and document rules/best practices for how to document anomalies
  - Main goal is to achieve the needed consistency and robustness across missions
  - Anomaly Management Best Practices Handbook (or comparable)
- Utilize a centralized, independent operations mission assurance team to verify adherence across missions to requirements and best practices
  - Provides ability to recognize and correct problems early

Implementation Approach (cont)

- Utilize a centralized anomaly trending and analysis team to perform various trending and analysis functions within and across missions
  - Assist in development of Mission Configurations
  - Analyze trends
  - Extract “lessons learned” and work to apply them across the relevant organizations, documents, etc.
    - Implement a “Lessons Learned CCB” with broad participation to disposition potential/proposed lessons learned and best practices
- Utilize a centralized database to capture problem report data that provides ability:
  - For individual missions to document, track, and close out their problems
  - For the Center to perform various analysis and trend functions across missions
  - To handle development/test (pre-launch) and operations phases
  - To handle flight and ground problems
  - To bring in data from outside users
  - To provide broad access, but with appropriate access protections (for ITAR sensitive and proprietary data)

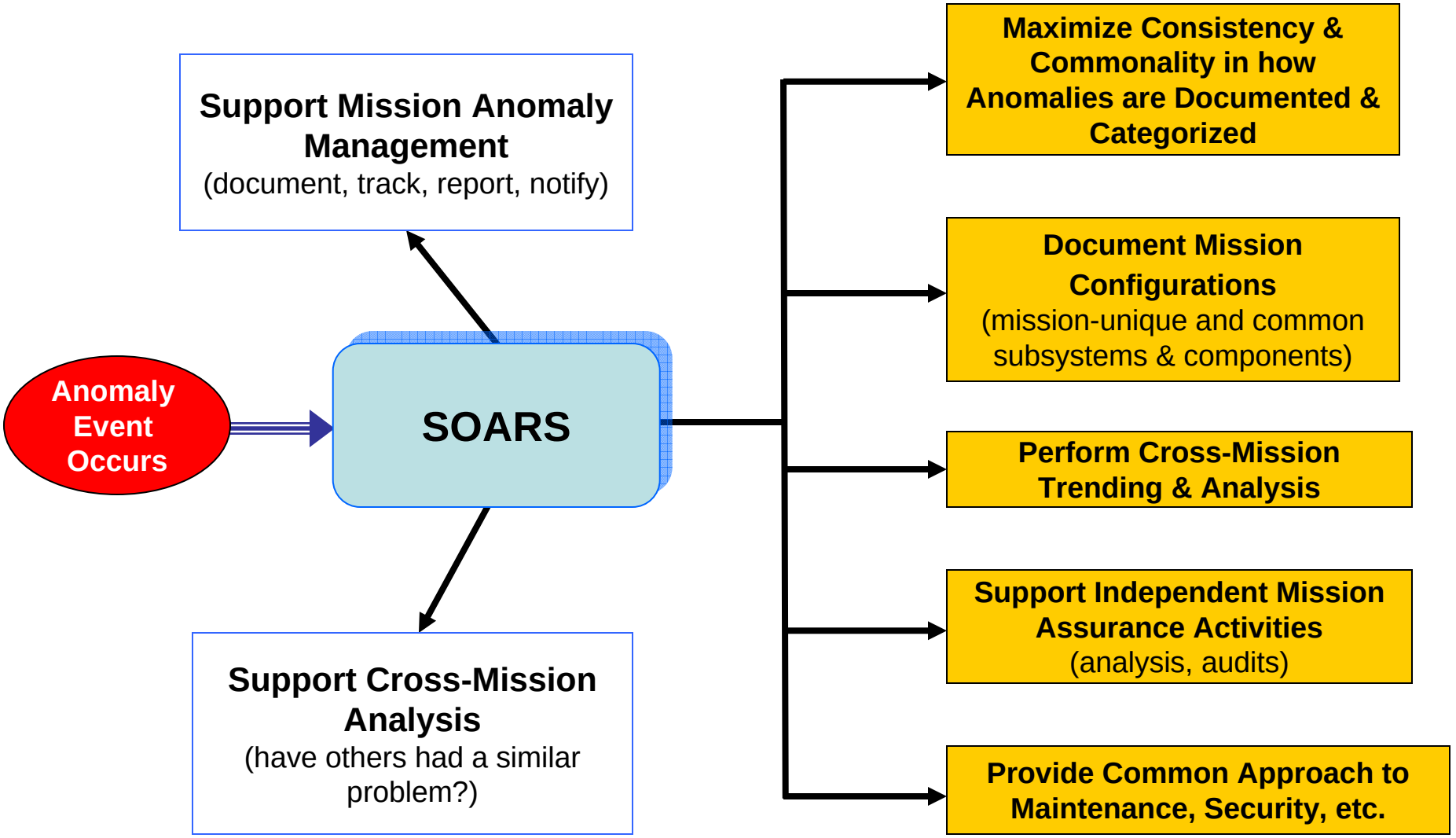
Implementation Approach (cont)

- The centralized database is the Goddard Problem Reporting System (GPRS), which contains two modules for documenting and managing ground and flight segment problems
  - Both provide multi-mission, web-based, secure user access
  - Other features include Mission Configuration definition, search/query capabilities, user notification (via email), user privilege control, user problem reporting, and attachments

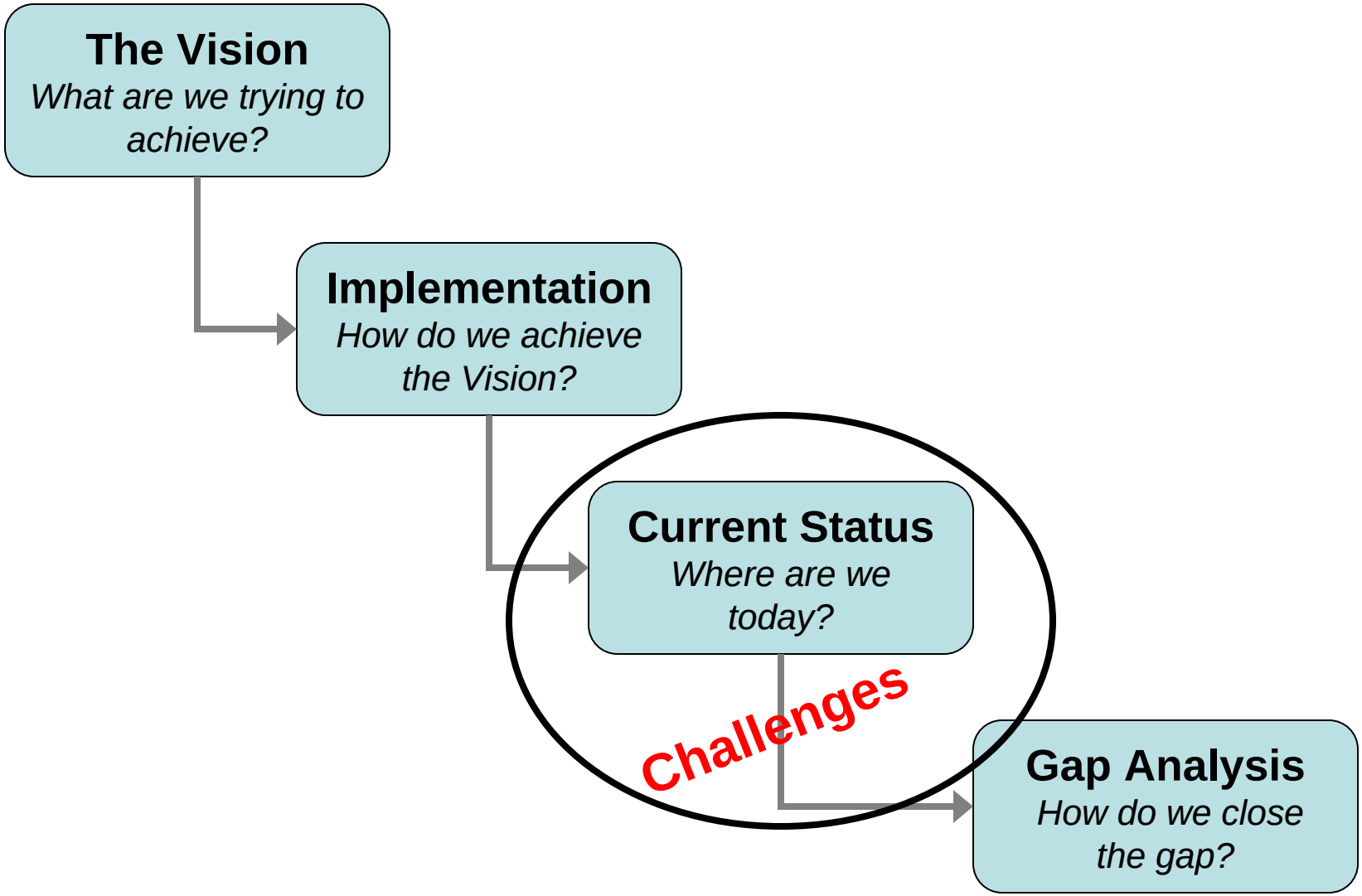
- SOARS -- Spacecraft Orbital Anomaly Reporting System
  - Used to document flight and ground problems during operations
  - Problems categorized via a common approach, using various Categorization Fields (Anomaly Classification, Impacts, Root Cause)

- PR/PFR -- Problem Reporting/Problem Failure Reporting System
  - Used to capture problems encountered during the development, integration, and test
  - Similar to SOARS, but tailored to the I&T environment (e.g., the signature process)

SOARS Model


Support Mission Anomaly Management
(document, track, report, notify)
Anomaly Event Occurs
SOARS
Support Cross-Mission Analysis
(have others had a similar problem?)
Maximize Consistency & Commonality in how Anomalies are Documented & Categorized
Document Mission Configurations
(mission-unique and common subsystems & components)
Perform Cross-Mission Trending & Analysis
Support Independent Mission Assurance Activities
(analysis, audits)
Provide Common Approach to Maintenance, Security, etc.

Current Status:
Where Are We Today?



Current Status

- Requirements & Best Practices Development/Compliance
  - High-level requirements associated with using GPRS and performing quality assurance, trending, and analysis are in place
    - GPR 1710.H - Corrective and Preventative Action
    - GPR 5340.2 - Control of Nonconformances
  - Mission Assurance Requirements Documents, with the Mission Assurance Guideline (MAG) document as a template also generally cover the requirements
    - But, capturing problem information in the central PR/PFR System limited to in-house missions for pre-launch phase
  - Operations Rules/Best Practices not yet formally documented in a central location that would apply across all missions
    - Exist in pockets within missions, families of missions, and Programs
    - Working with missions and Programs to begin development

Current Status (cont)

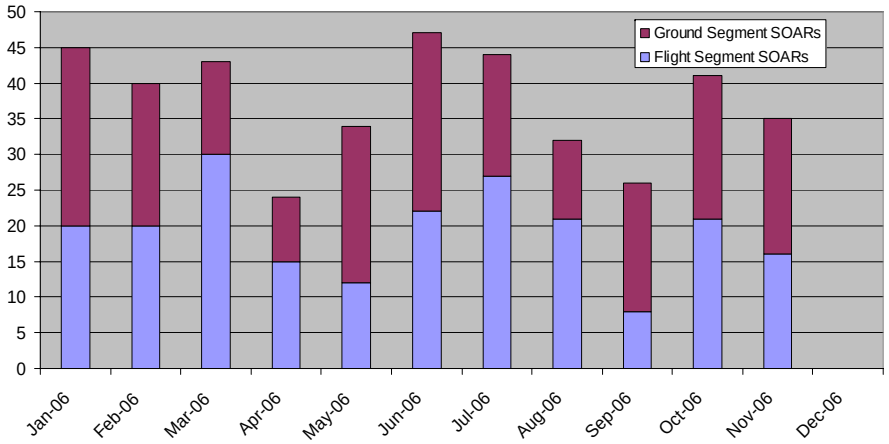
- Operational Improvements
  - Major GPRS enhancements made to SOARS and PR/PFR software over the last year to improve operational usability, etc.
    - SOARS now considered an operationally useful tool, with ongoing activities to continue incremental improvements
    - PR/PFR has more recently undergone improvement, largely driven by two Goddard in-house missions (SDO and LRO)
      - PR/PFR needs much more improvement to “catch-up” to SOARS
  - SOARS use by the operational missions has increased dramatically over the last year
    - One year ago very few missions were using SOARS at Goddard
    - Almost all in-house missions (~20) now using SOARS effectively, including RXTE, Terra, Aqua, EO-1, and TDRSS
    - Only one out-of-house mission currently populating SOARS with anomaly report data (Swift at Penn State University, as a direct user)
      - Other out-of-house “operations vendors” include APL, Orbital, LASP, and University of California at Berkeley (UCB)
      - Currently working with these organizations to develop plan for populating SOARS (e.g., make use of data import)

Current Status (cont)

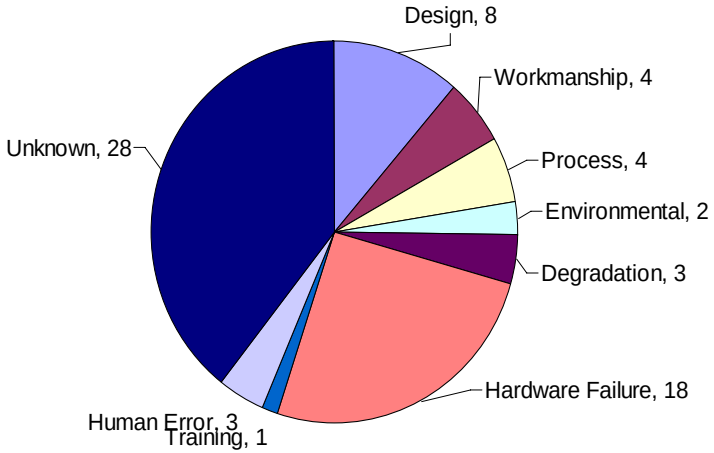
- Anomaly Analysis and Trending
  - Centralized teams in place within Office of Mission Assurance (Code 300) for performing roles of operations mission assurance and cross-mission anomaly analysis and trending
    - Development phase handled by individual Code 300 System Assurance Managers (SAM's) assigned to missions
  - GSFC (Code 300) using SOARS data extraction to:
    - Provide monthly Center-wide snapshot of mission anomalies, characterized by Mission Impact, Operations Impact, and Root Cause
    - Develop annual "year-in-review" anomaly summary report (OAGS)
    - Trend and analyze problems across missions, subsystems, failure types, etc.
    - Support long term reliability studies on flight hardware
    - Identify missions that are not adequately documenting anomalies and work with them to improve

SOARS Data Extraction – Example 1

SOAR Records - All active Goddard Missions
(12 month summary)



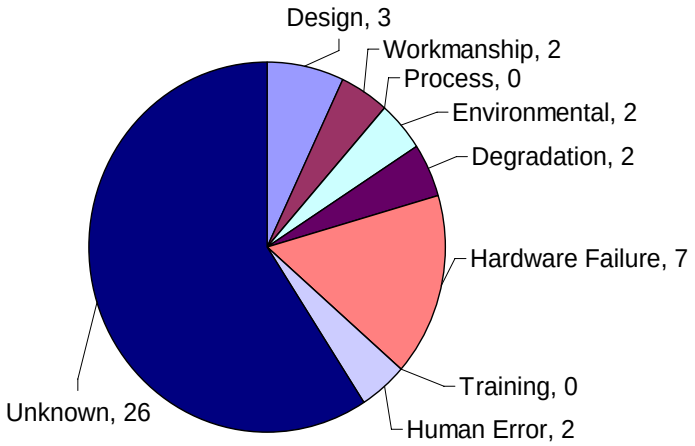
Root Cause Categorization for Cum CY06 "Ops Workaround" SOAR's



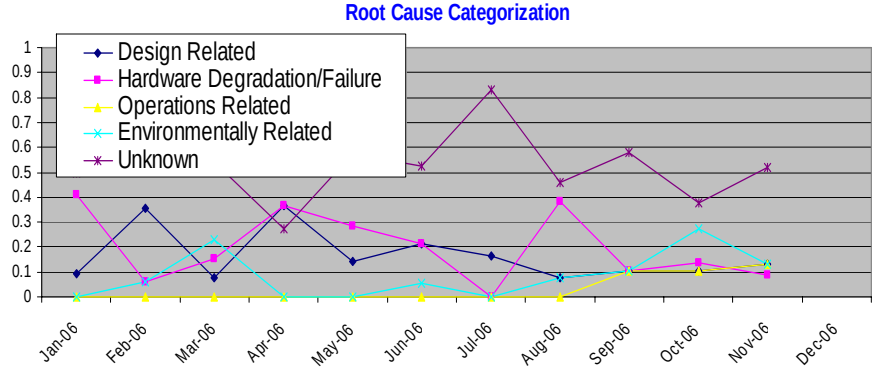
Significant Nov'06 On-orbit Anomalies

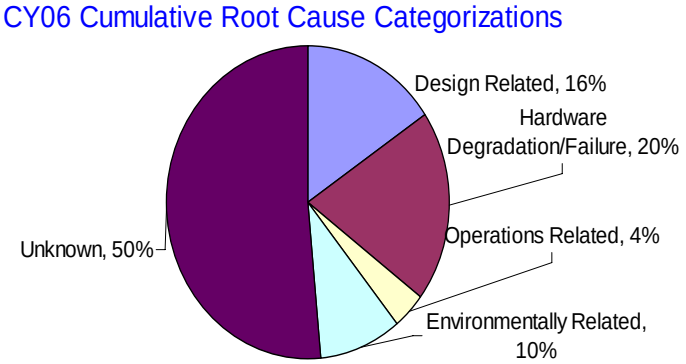
- **Msn-X power load shed anomaly**
  - All science instrument main voltages shed in accordance to the Under Voltage protection Circuitry
  - Under voltage condition, possibly indicating a failure (short) somewhere in the affected loads
- **Msn-Y Star Tracker and Sun Sensor Boresight anomaly**
  - Star Tracker alignment calibration analysis indicates over a 2 arc-minute shift in the alignment between the Star Tracker and FSS
- **Msn-Z ACS Quaternion Spike Error anomaly**
  - Star Tracker Quaternion element was corrupted
  - Spacecraft commanded to Sun/Mag pointing and the Star Tracker stabilized

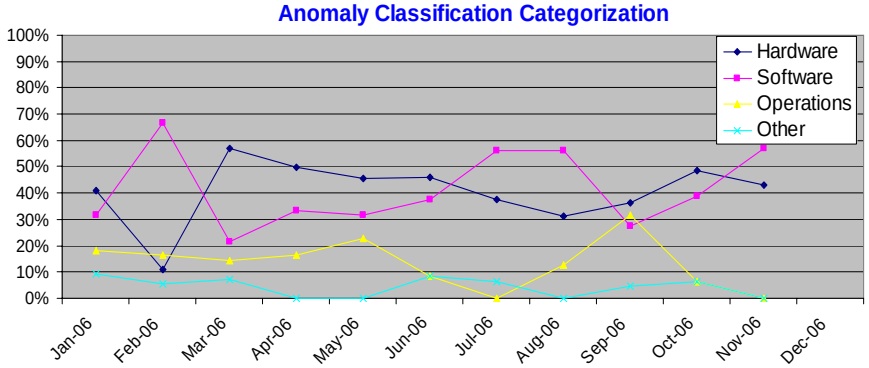
Root Cause Categorization for Cum CY06 "Data Loss" SOAR's

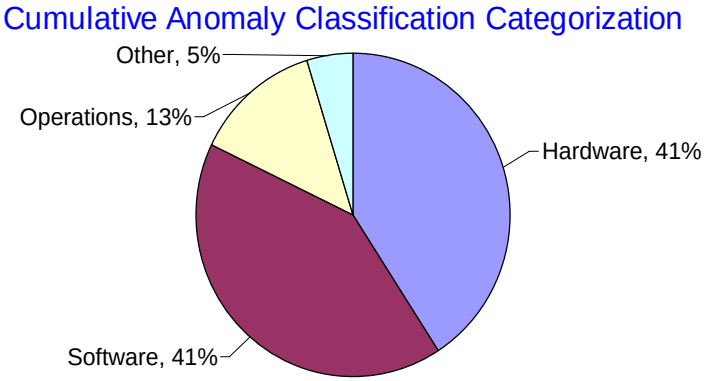


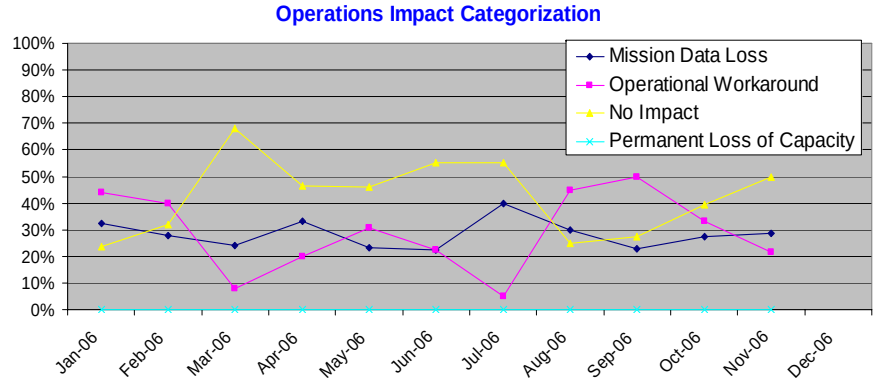
SOARS Data Extraction – Example 2

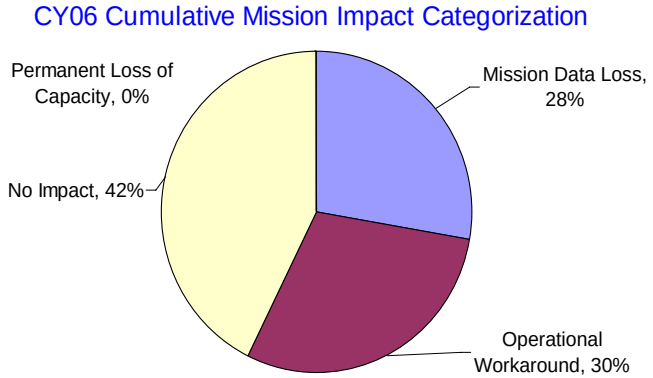












Current Status (cont)

- Inserting “Lessons Learned” into the Process
  - Implementing an “Operations Lessons Learned” process, but still in the very early stages
  - Plan is to implement a process where a Lessons Learned Committee/Board is presented with potential lessons
    - Committee determines if lesson valid, and if so, the actions that are appropriate to take it forward
    - Working to engage broad participation (mission assurance, missions, and engineering)

Examples:

- Ops best practice update
- Improvement in testing
- Feedback on hardware performance issues
- Recommendation to flight software group
- Recommendation for “Gold Rules” update

Sample Lessons Learned Summary

Mission	Anomaly Date	Anomaly Description	Proposed Lesson Learned	Action
Msn_X	10/3/06	Spacecraft clock rollover to an illegal 1998 date; on-board clock register capacity was exceeded.	Establish best practice of evaluating registers prior to launch, and as part of the on-orbit ops procedures. Include FSW capabilities to issue warnings when appropriate.	Work directly with Ops Projects to document as Ops Best Practice. Work with Flight Software Branch to determine if design best practice needed.
Msn_Y	10/19/06	UV instrument experiencing channel noise, apparently associated with heater activation and environmental conditions. Causing failure of instrument to meet signal to noise ratio requirements for the data channel.	Lesson tbd, but would apply to improving test approach. Seems this should have been caught in instrument or observatory I&T. Why was this not seen during thermal vac? Does this have implications to other missions? Could or should this instrument sensitivity have been better tested during instrument I&T?	Investigate further. Discuss with Msn_Y SAM and I&T Manager. Generate independent analysis report if warranted.

Implementation Challenges

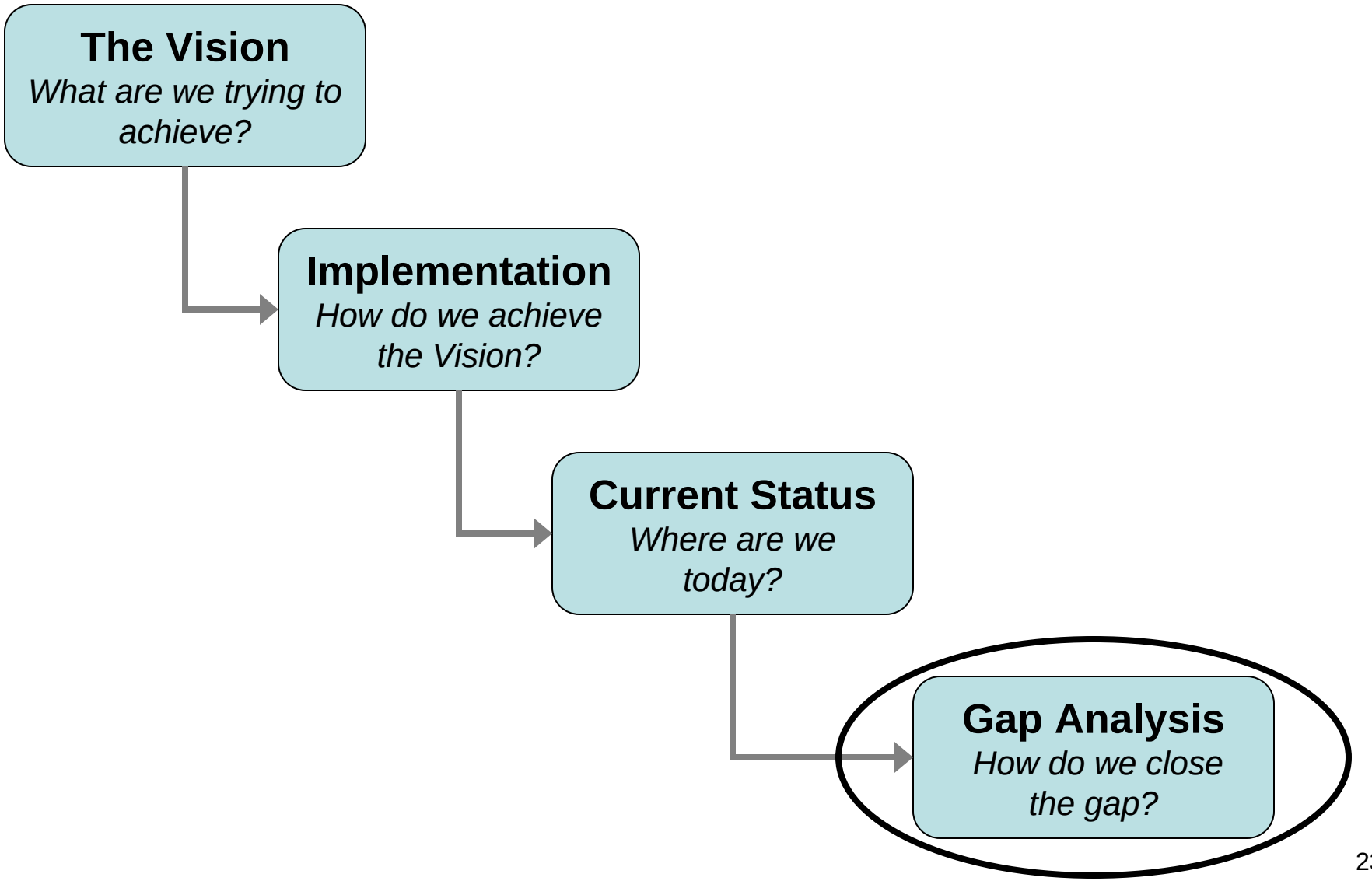
- Achieving consistency across missions in how anomalies are documented (e.g., terminology, level of detail) and categorized is proving to be very difficult
  - Many missions with different ops teams have different taxonomies, operations cultures, etc.
  - Missions themselves also very different in terms of bus design, payload suite, operations profile, age, and risk tolerance
- Mission Configuration definitions in SOARS not well-defined across all missions, making it difficult to perform cross-mission analyses
  - Not all information is readily available to use in SOARS definitions, especially for older missions (e.g., component manufacturers and design life)
  - Missions have struggled to put in the extra time to populate SOARS with their Mission Configurations
  - Working with the existing missions to improve the definitions, but effort is time consuming and challenging
  - Working with upcoming missions to get the definitions in place prior to launch (e.g., GLAST, SDO, and LRO)

Implementation Challenges (cont)

- Proving very difficult to get out-of-house operations centers/teams to document problems in SOARS
  - Only one direct user so far (Swift/PSU)
  - Working with others to take advantage of enhanced SOARS data import capability
  - Finding that the critical factor is getting the agreement more explicitly planned well before launch

- Only getting pre-launch problem report data into PR/PFR for in-house missions
  - Leaves a big “information gap” given the high number of out-of-house missions
  - Vendors cannot use PR/PFR directly, but working to determine if certain types of problem report data can be imported into PR/PFR

Gap Analysis



Gap Analysis:
How Would You Complete "The Job"?

1. How would you approach achieving and maintaining more consistency across missions in how anomalies are documented?
   - Getting them to do it consistently over time
   - Working to measure/enforce consistency over time

2. Do you think it is possible to develop a set of Operations Anomaly Management Best Practices that would reasonably apply across a set of heterogeneous missions, that are a mix of in-house and out-of-house operations approaches?
   - If so, how would you approach getting this defined and keeping it updated?
   - If not, what can be done? Do you just give up?

3. What type of information besides the basic anomaly information would you want to capture for your missions to support long term trending, reliability/failure analysis, etc?

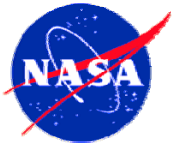
Gap Analysis:
How Would You Complete "The Job"?

4. How would you ensure that the relevant Mission Configuration information for upcoming missions is documented so that it is usable by the problem management system?
   - Address the in-house vs. out-of-house challenges

5. How would you approach getting more out-of-house operations centers/teams to document their anomalies in the centralized problem information system (SOARS)?

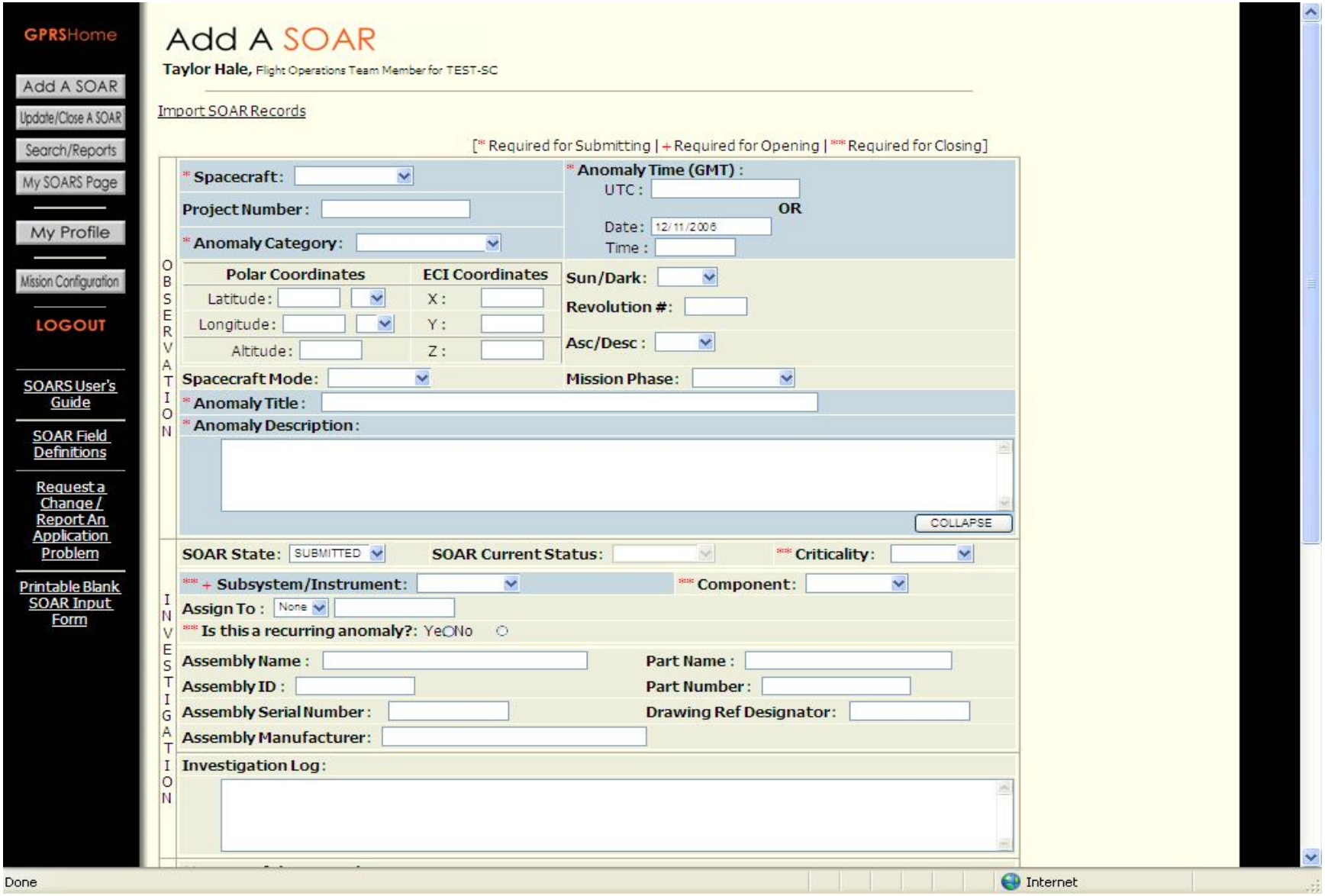
6. How do you extract problem information from out-of-house mission vendors for use in the centralized problem information system (PR/PFR) during the pre-launch development phase?
   - Will likely have proprietary data issues

7. How do you integrate lessons learned into projects/programs so that they will actually affect mission development and operations, and maintain benefit over time?

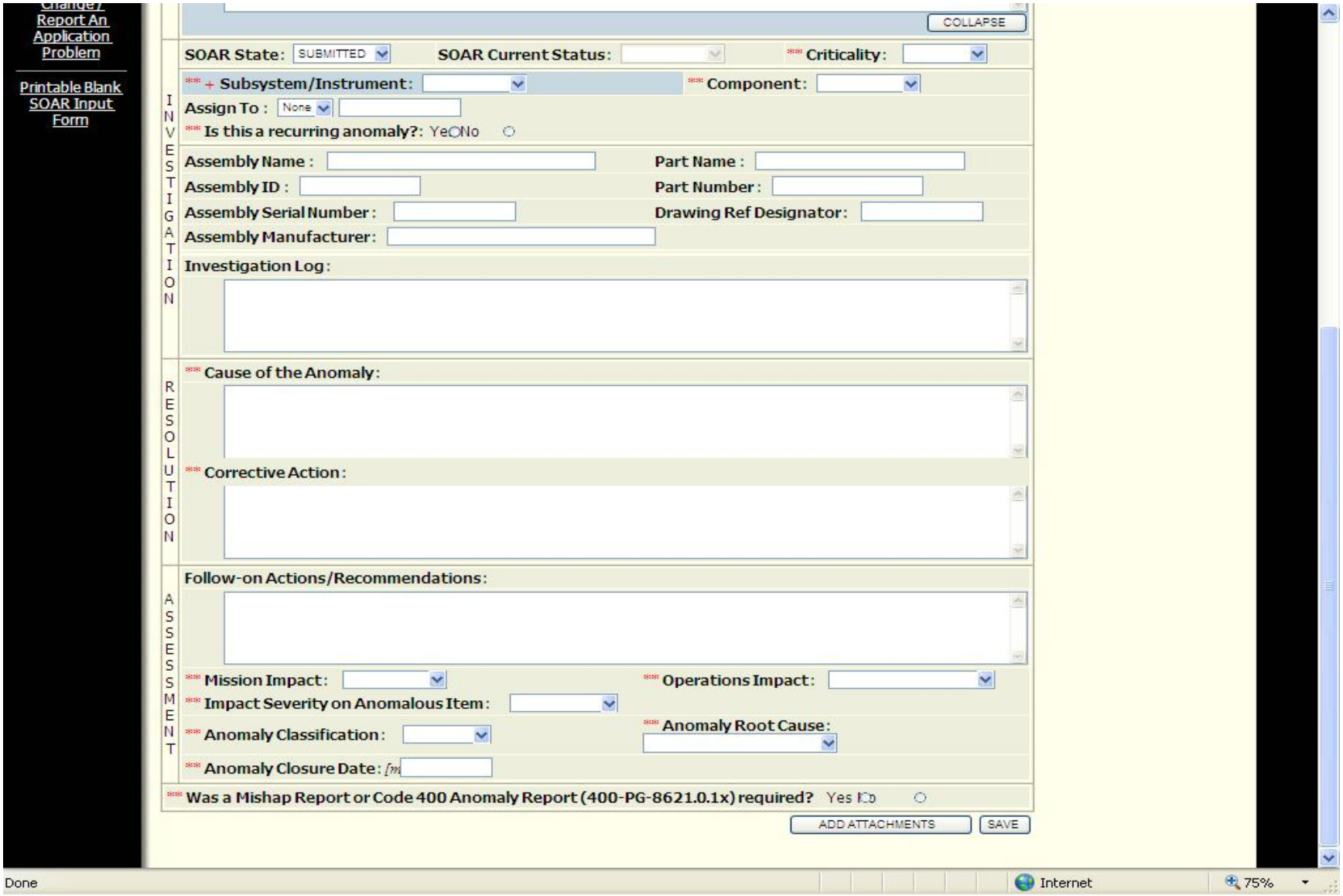


BACKUP SLIDES

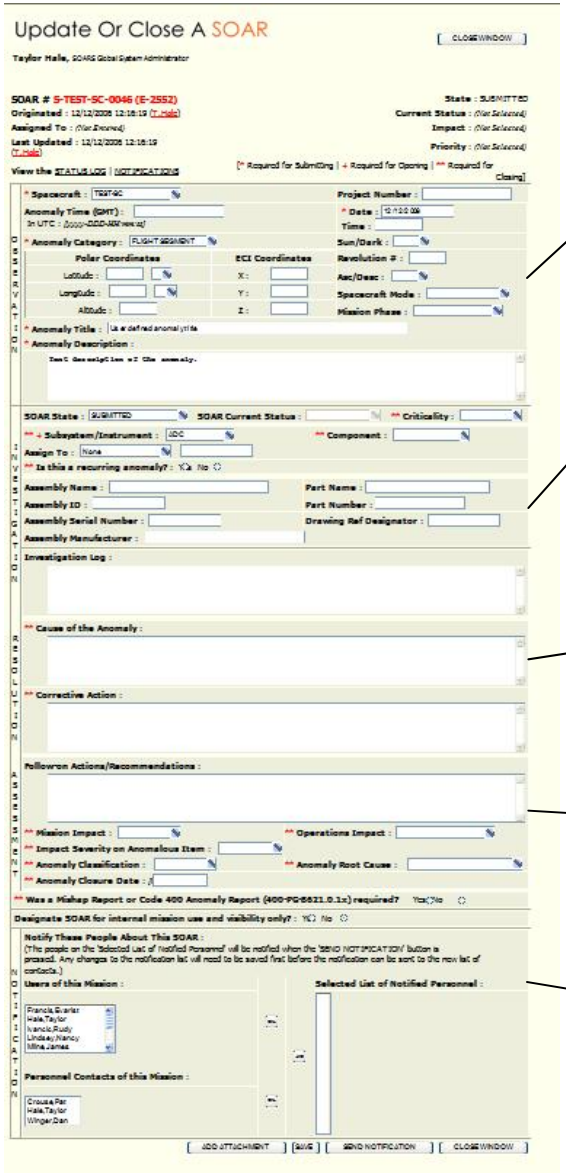
SOARS Anomaly Report Form



SOARS Anomaly Report Form (cont)



SOARS Anomaly Report Form



Observation area includes all problem descriptions including orbit and attitude data, and other user defined fields

Investigation area provides a place for the operations team to document the problem investigation and status. Includes an investigative log, subsystem and component identification, anomaly criticality, status, and responsibility assignment.

Resolution area provides the operations team an text area to capture a synopsis of the problem cause and resolution.

Assessment area is used to identify follow-on activities or recommendations and categorize the SOAR for generic use.

Notification area is used to send email notifications to personnel (either other SOARS users or other contacts identified by missions)

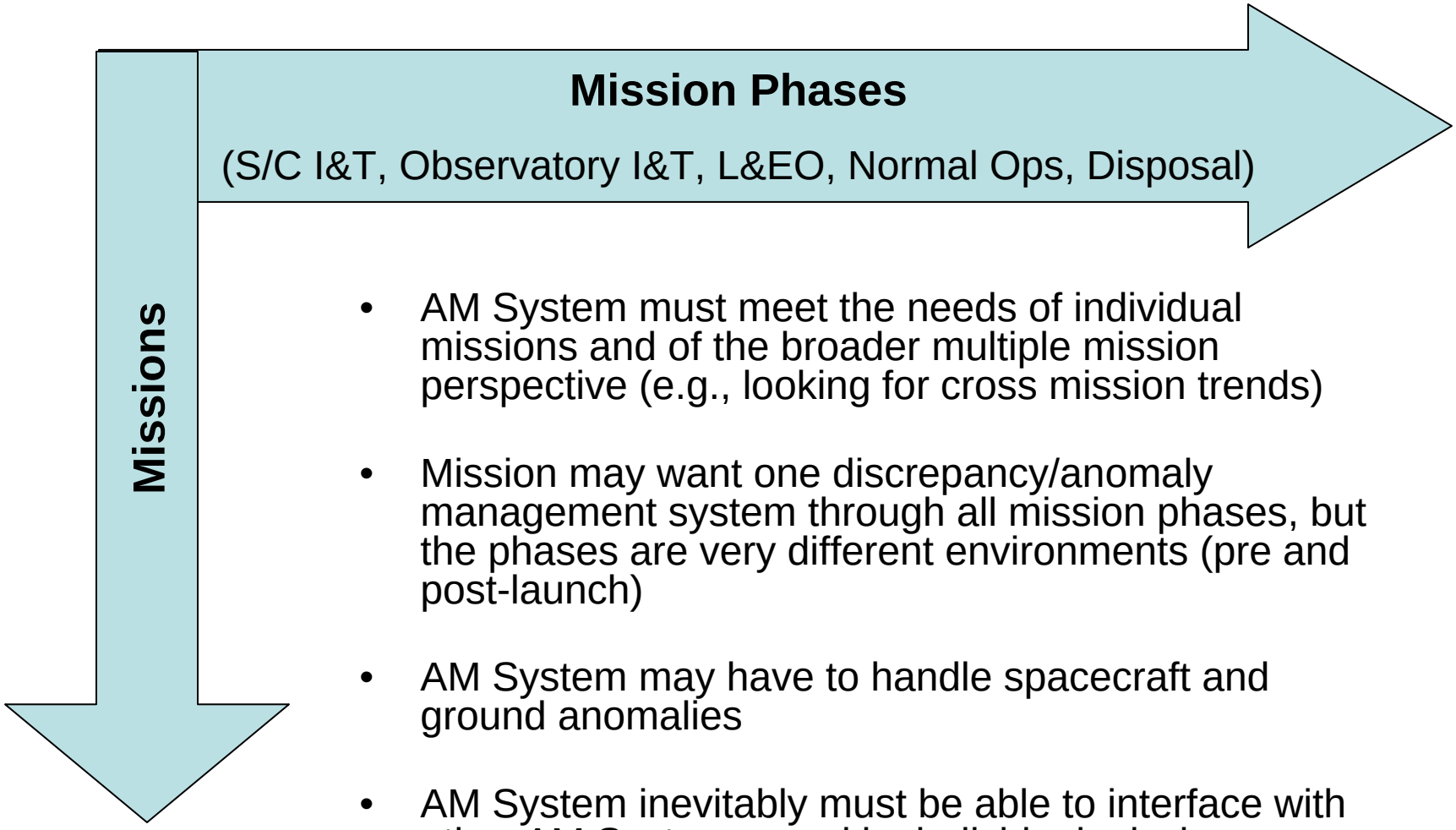
SOARS Data Summary

- All SOARS anomaly reports will include the following information:
  - Anomaly occurrence time
  - Anomaly title
  - Anomaly category (flight or ground segment specification)
  - Anomaly Subsystem and Component identification
  - Anomaly description
  - Closure information
  - Follow-on recommendations
  - Anomaly categorization
- SOARS may include the following types of information:
  - Anomaly assignment and responsible party
  - Investigation information
  - Orbital information
  - Mission unique phase and mode
  - Additional file attachments as appropriate

SOAR Data Categorization

- SOAR ***Categorization Fields*** are the key fields used for trending and analysis across missions for the Center. The fields include:
  - ***Mission Impact***: describes the actual anomaly impact on the ability to meet Science and/or Mission Goals or requirements
    - No Effect, Minor, Substantial, Major, Catastrophic, Undetermined
  - ***Impact Severity on the Anomalous Item***: describes the actual impact to the subsystem or component where the anomaly occurred
    - No Effect, Minor, Major, Catastrophic, Undetermined, Not applicable
  - ***Operations Impact***: describes the effect of the anomaly on mission and/or science operations
    - Data Loss, Service Loss, Mission Degradation/Loss, Undetermined, Ops Workaround, None
  - ***Anomaly Classification***: describes where within the mission systems the failure occurred
    - Hardware, Software, Operations, Other
  - ***Anomaly Root Cause***: describes the root cause of the anomaly.
    - Design, Workmanship/Implementation, Process, Environmental, Degradation, Hardware Failure, Training, Human Error, Unknown

One Size Fits All Anomaly Management (AM) System: Does It Exist?



- AM System must meet the needs of individual missions and of the broader multiple mission perspective (e.g., looking for cross mission trends)
- Mission may want one discrepancy/anomaly management system through all mission phases, but the phases are very different environments (pre and post-launch)
- AM System may have to handle spacecraft and ground anomalies
- AM System inevitably must be able to interface with other AM Systems used by individual missions